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Automatic Estrus Detection System for Dairy Animals

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***Abstract*- This paper deals with the new aid for detection of Estrus (Heat) in dairy animals. As dairy Technology is developing day by day, therefore reproductive performance of dairy animals is major concern in dairy industry. This Reproductive performance of dairy animals requires accurate and regular Estrus detection. Estrus is nothing but a behavioural symptom in mammals which indicate that female is mated close to the ovulation. That's why Timely detection of estrus is the only solution to increase the fertility rate in dairy animals. Failure to detect animal in estrus and breeding animals which are not in estrus result in economic loss for the owner because of extended calving interval and additional semen expenses. Accurate Estrus detection gives idea about proper timing of Artificial Insemination. So Estrus detection is the key solution for effective growth in dairy technology. During estrus period animal shows mounting behaviour, increased physical activity and vaginal temperature of animal is increased. So, in proposed technology, for the very first time all these three signs are sensed by three sensors. The signal from the sensors are given to the micro-controller, then micro-controller process the data, display the data on LCD screen as well as transfer all the data wirelessly to the Personal computer (PC). PC runs a software module which display all the data i.e. Animal name, number of mounting, physical activity and vaginal temperature.**

***Index Terms*- Estrus (Heat) detection aids, pedometer, mount detector.**

I. Introduction

Indian economy is one of the growing economies in the world. As livestock and animal husbandry are major contributing sector in Indian economy also they are stable sections and require less investment. So, more attention has to be paid to raise the investment in these sectors [1]. India has about 20% of the world's total cattle population and 50% of buffaloes, most of which provide nutritious milk to enrich Indian diet. India is the largest milk producing country in the world with the total milk production of 109 million tonnes [2]. Despite of holding number one position in milk production, average milk production per cattle is very less as compared to other leading countries.

The main cause for low average productivity is low fertility rate in dairy animals. Artificial insemination is the key solution to increase the fertility rate in dairy animals. For successful artificial insemination, it is very necessary to inseminate the animal just after the ovulation [3]. Estrus is nothing but a behavioural symptom in mammals which indicate that female is mated close to the ovulation. That's why Timely detection of estrus is the only solution to increase the fertility rate in dairy animals. Failure to detect animal in estrus and breeding animals which are not in estrus result in economic loss for the producer because of extended calving interval and additional semen expenses[4]. Estrus is combination of internal invisible events as well as external and visible signs of ovulation [5].Incorrect detection of estrus or failure to detect estrus causes annual loss in dairy industry [6].

Animals which are in estrus period show two types of signs. First one is internal changes that are genital changes and the second is behavioural changes which are external changes [7]. Some estrus signs are:

i] Mounting behaviour in dairy animals is the best indication for detection of estrus. Mounting means particular animal in estrus period allows other herd mates to mount on her while she remains standing.

ii] Physical activity of that animal is increased.

iii] There is drop in milk production and in food intake of the animal

iv] A thin, clear, watery mucus discharge from vulva is sign of estrus

v] Swelling and reddening of the vulva

vi] The temperature of genital areas is slightly increased by 1 degree Celsius.

II. Literature Survey

There are lots of instruments available for the detection of estrus which is based on the above estrus signs. In India, generally the animal owners prefer individual animal observation because of traditional practices and very less investment. Animals can be observed for estrus detection using CCTV or Video recording [8]. So this process is quiet tedious one because observing each animal in the herd where number animals are more is hard task. Second method used is keeping animals like teaser bulls or nymphomaniac cows or sniffer dogs [9]. These animals get mount on the animals which are in estrus period, but keeping such animals increases investment on maintenance of them. Third method is use of tail paints and dyes such as KAMAR paints, theses tail paints or pressure sachets placed on tale head area of animal [10]. So if the animal gets into estrus period because of mounting activity of other animals these pains get fed or the pressure sachets get burst out, which is the indication of estrus condition. But in this method there are lots of chances of false detection means because of false mounting also these dyes get fed up and give wrong indication. In next method mucus, blood and milk is tested in the laboratory [11]. If the estrus period is there then that mucus of particular animal shows fern like structure under the lycoscope. The blood and milk samples are tasted for progesterone and Oestrogen levels.

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Again this method is time consuming and increase capital investment. The best method is to use electronic devices which are automatic one, requires fewer efforts, low investment and gives highly efficient results [12].

Mounting activity in the animals is major sign for estrus detection. Because of mounting activity the pressure sensor shows a change in pressure or the dye or colour gets spread out. In early 80's, (Patent No. 4,206,766) Depressible spring is used to detect the mounting activity. The pin's motion is transferred by the linkage mechanism to the release mechanism, which then disengages an outer cover causing it to fall away and deploy an estrus indicating streamer [13]. In another design (Patent no. 4,411,274) fastened transmitter is attached to the female animal. This generates a signal which is received at a distant point and recorded. The transmitter consists of time delay circuit to pause for a predetermined period before signal generation; this pre-determined period is given to avoid false positives. A magnetic switch is used to give signal to time delay circuitry. The receiving unit consists of standard receiver and microprocessor [14]. In The next patent (Patent no. 4,846,106) includes an electronic timer module connected to the membrane switch. The system consists of a digital timer display, a mounting counter display; a flashing clock signal to indicate activation of the module, as well as audible and visible indicators. The switch actuates the timer, the mounting counter, the flashing clock display and it also actuates the audible and visible indicators [15].

In electronic estrus detector system [16], a tape switch is connected to the counter for storage and display of the number of mounts. In advance technology [17], a device is designed for detection, analysis and telemetric signal conditioning of a signal- detecting estrus. The apparatus consist of self contained power source, a force responsive sensor, controller, a transmitter and an antenna and a fluid tight capsule. The apparatus analyses the duration of mounting. The heat detection system employs a single handheld receiving unit which remotely communicates with multiple individual recording units secured to the backs of the cattle. The receiving unit can remotely and selectively reset counters contained within the recording units and can remotely and selectively poll the recording units to obtain data on mounting activity for each cow. The displayed data can be downloaded to a computer via the computer port provided on the receiving unit [18]. The research in this field lead to the invention of a system which permits the accurate determination of optimal breeding time, natural or artificial, based on mounting activity. The device includes a water-resistant housing, which contains the electronic portion of the device consisting of a controller, power source, activation means, and at least one display. The device determines and subsequently indicates suspected and confirmed estrus based on an algorithm [19].The product available based on mounting activity are *HeatWatch II* [20], *ShowHeat* [21], and *MountCount* [22].

The increase in physical activity during estrus in dairy cows was first described by Farris in 1954 in a study on 13 Guernsey cows [23]. Later, Kiddy evaluated the mean variation in physical activity of dairy cows in estrus using pedometers for human use [24]. The devices were attached to the cow's rear ankle using a strap. The study collected data on 87 estrus periods observed in 40 Holstein cows in a free stall barn, in which the average increase in movements during estrus was 393% compared to activity during non-estrus periods. These two studies were the basis for the development of activity systems for heat detection [25, 26]. Increased activity and low progesterone during estrus are strongly related to each other (Figure1). Activity monitoring can be an accurate tool for estrus detection. *Afiact* system is part of *Afimilk* used for milk collection. The system collects a activity data attached to the cow's leg [27]. In another device called SelectDetect neck mounted activity monitors are used to collect activity data and then this data is wirelessly uploaded periodically to the base station [28].

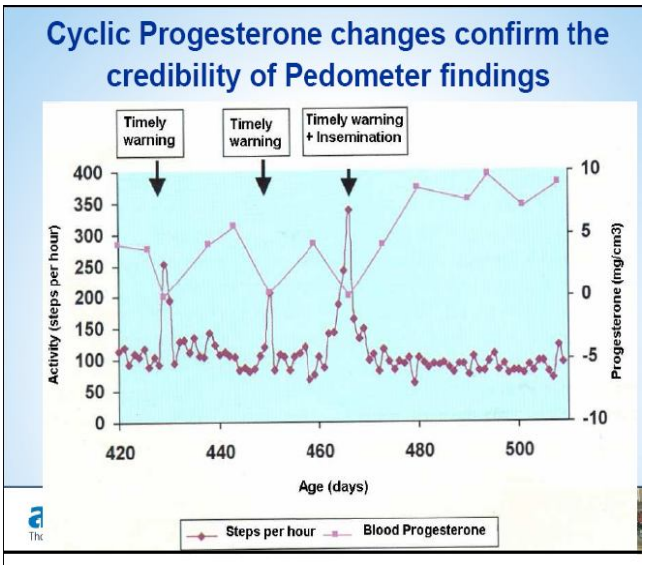

Fig.1 Activity Detection with Hormone Change. **(**Courtesy: Graph provided by Afimilk showing correlation between activity (steps/h) and progesterone levels.)

Body temperature changes during the estrus cycle [29]. A rise in temperature can be detected around the LH-surge during the estrus [30]. This may be caused by a higher level of activity during estrus, but the mechanism behind the temperature change is not clear. In [31], the author detected 81% of estrus cows by measuring vaginal temperature, with 14% false positives. So change in body temperature is sign of estrus condition.

The available technologies use these parameters as individual instrument, but in proposed system these three parameters are combined so that the result is more reliable and accurate one [32]. It is observed that during estrus period other herd mates stand to be mounted on the animal which is in estrus phase. It is also called standing

heat. So for the detection of standing heat, special type of pressure sensor is used. This pressure sensor is mounted on the tale head area of the animal. When the animal is in estrus condition other herd mates get mount on this animal, which causes increase in pressure. This increase in pressure is detected by pressure sensor and the signal is given to the

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micro-controller. For the detection of increased physical activity pedometer is used. This instrument is used to count the number of steps taken by the animal. So if the number of steps recorded by the instrument is far more increased than the normal records, then it is the indication of estrus period. Sensor used in pedometer is accelerometer, which gives change in output proportional to the change in acceleration. For the detection of change in vaginal temperature, we have used a Temperature sensor called LM35. This temperature sensor can sense the temperature of the atmosphere around it or the temperature of any machine to which it is connected or even can give the temperature of the human body in case if used. So, irrespective of the application to which it is used, it gives the reading of the temperature. The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to The Celsius (Centigrade) temperature.

III. Hardware Details

The proposed system consists of mounting detector circuit, pedometer, micro-controller, LCD display and Battery operated power supply. Fig.2 shows the block diagram of proposed system and Fig.3 shows experimental set up.

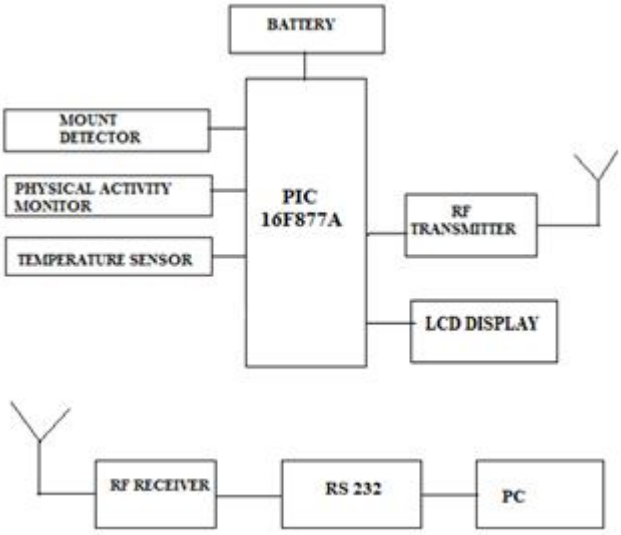

Fig.2 .Block diagram of proposed system

Fig.3. Prototype image

A. Mount Detector

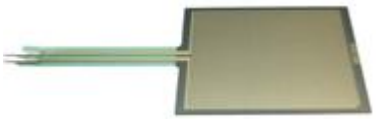

Fig.4.Flexiforce sensor FSR406

As mentioned earlier the mounting activity in the animals is detected by the pressure sensor. The sensor used in proposed system is Force sensing resistor FSR 406 (Ref. Fig.4). Force sensing resistors are robust polymer thick film, two wire devices that exhibit a decrease in resistance with increase in force applied to the surface of sensor. Fig.6 shows the force versus voltage characteristic of the FSR sensor.This sensor has easily customizable to a wide range of sizes, ultra thin, low cost and they are simple and easy to integrate. For Simple force to voltage conversion, the FSR is tied to the measuring resistor in a voltage divider and the output is given by the following equation.

$$V_{out} = R_M V / R_M R_{FSR} \quad (1)$$

Where,

Vout- Output Voltage

R_M - Measuring resistor R_M, is chosen to maximize the desired force sensitivity range and to limit current.

R_{FSR} – Resistance of FSR

The output of the force to voltage (Ref. Fig5) converter is given as input to the one of the channel of internal ADC of micro-controller. Therefore when there is no force output of ADC is low and when there is force the output of ADC is high. This output of ADC is read by micro-controller. The number of mountings is displayed on LCD display.

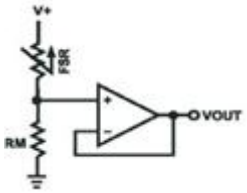

Fig.5. Force to voltage converter

For Rm = 100K

The sensor readings are listed in table below:

Table I. Output of sensor at different force

Serial No.	Force in grams	Voltage in volts
1	0	1.5
2	20	2.5
3	50	4
4	100	4.5

The construction of system is such that the force sensor is placed in between rigid rubber material. This sensor is placed on the tale head area of the animal. When mounting occurs, the force equal to the weight of the animal is applied on the rigid rubber material. Because of rigidity, the pressure gets reduced and the limited pressure present on the force

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sensor. The micro-controller detects the change in pressure signal and records it as one mount. The number of mounts is displayed on the LCD display as well as the data is sent to the PC.

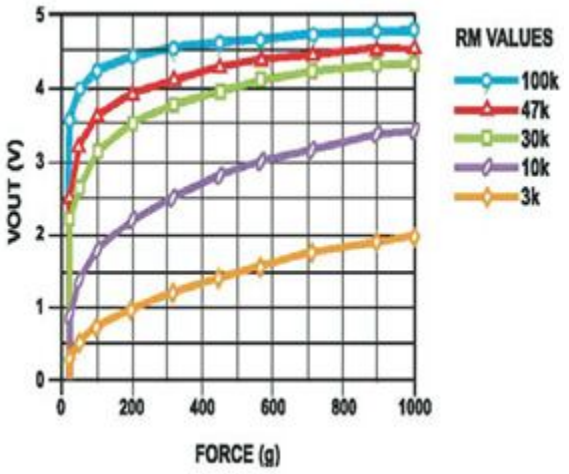

Fig.6.Graph showing force verses voltage characteristic of sensor

B. Pedometer

Fig.7. ADXL335 Accelerometer

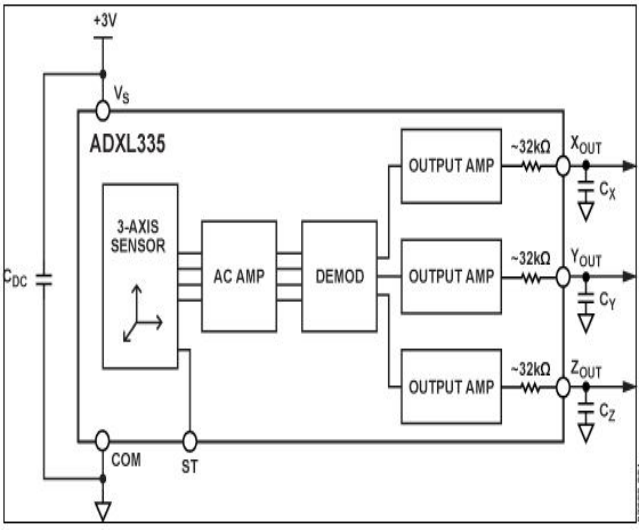

Fig.8 Functional Block Diagram of Accelerometer

An accelerometer is an electromechanical device that will measure acceleration forces. These forces may be static, like the constant force of gravity pulling at our feet, or they could be dynamic - caused by moving or vibrating the accelerometer. By measuring the amount of static acceleration due to gravity, one can find out the angle the device is tilted at with respect to the earth. By sensing the amount of dynamic acceleration, one can analyze the way the device is moving. Accelerometers use the piezoelectric effect - they contain microscopic crystal structures that get stressed by accelerative forces, which cause a voltage to be generated. The three axis accelerometer are basically used to identify the movements across the three axis i.e. x-axis, y-axis, z-axis. The accelerometer used in this system is ADXL335 (Ref. Fig7), which is small low profile package, can measure minimum full scale range of +/- 3g. Functional block diagram of sensor is shown in Fig.8.

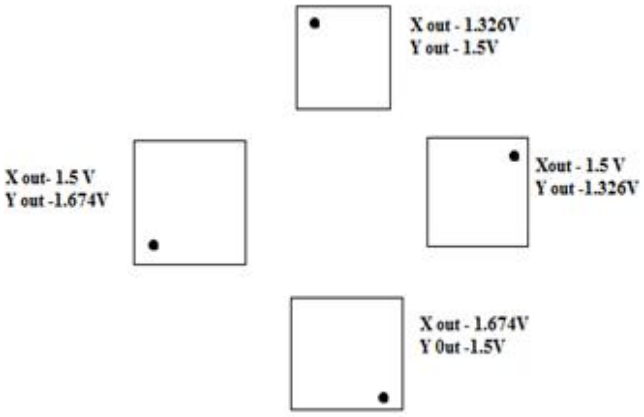

Fig.9.Output response of accelerometer sensor

Fig.9 shows the actual output response of accelerometer sensor. Accelerometer's output is given as input channel of ADC of micro-controller. When there is activity of leg, acceleration due to gravity changes causes change in output of accelerometer which ultimately changes the output of ADC. The micro-controller counts the number of steps, step count is displayed on the LCD display and the data is send to the PC. The construction of device is such that the sensor is mounted on belt and this belt is attached to the right leg of the animal. The sensor is well protected inside plastic coating. It must be waterproof and robust. This same sensor can be mounted at the neck area of the cow.

C. Temperature sensor

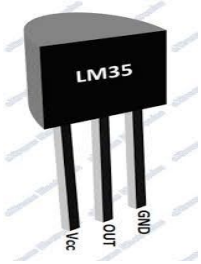

Fig.10. LM35 Temperature sensor

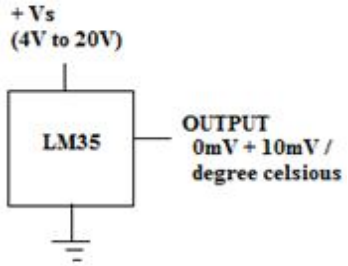

Fig.11.Basic centigrade temperature sensor

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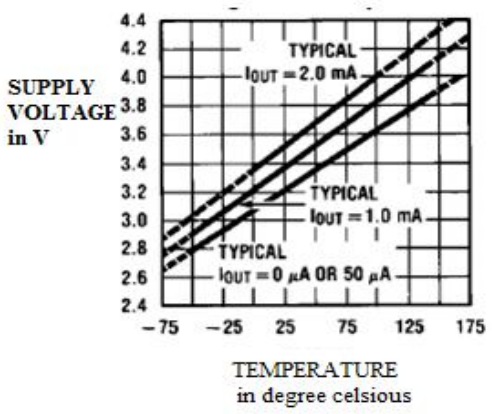

Fig.12. Graph showing temperature Vs voltage characteristic

As PIC µC has a inbuilt 8 channel 10 bit ADC. So, analog temperature sensor is connected to the analog port A. The LM35 (Ref. Fig.10, 11) series are precision integrated-circuit temperature sensor, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The LM35 does not require any external calibration or trimming. Temperature range is -55 to +150 ^{0}C. The LM35's low output impedance, linear output (Ref. Fig.12), and precise inherent calibration make interfacing to readout or control circuitry especially easy. The microcontroller read the data of ADC and displays it to the LCD as well as sends the same data to PC.

E. Wireless Transmission

Zigbee module is used for wire-less data transmission. The micro-controller transmit all the data to the tansmitter unit of zigbee and the receiver unit , which is at the PC side as shown in Fig.13,receives all the data and through RS232 the data send to the PC.On compter the VB module selects the comp port and run the program. The VB window display all parameter values as shown in Fig.14.

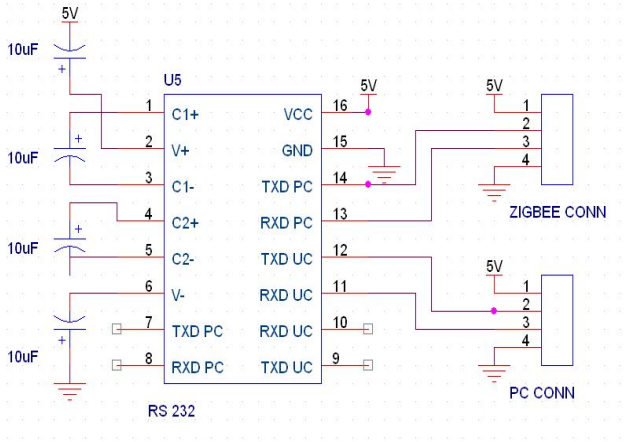

Fig.13. PC side Connection Diagraam

IV. Software Details

PIC16F877A is used as a micro-controller in a proposed system. The four sensors namely mounting sensor, accelerometer, and temperature sensor and mucus detector are interfaced with analog channel of ADC of micro-controller. The values of mount count, steps taken, vaginal temperature and mucus detector are displayed after every 2msec of delay. Power on reset function of PIC micro-controller resets all the values. For the power requirement a battery powered power supply is used.

To detect the number of mountings, the output of sensor is given to the input channel of ADC. And the output of ADC is read by microcontroller. The micro-controller read output of ADC after every 2 seconds. If the force is very low, it is considered as no force to avoid false mounting. When there is actual mounting means when sufficient force is present, it is considered as true mounting and counted as mount one. This initiates the counter, and the number of mountings displayed on the LCD.

For pedometer, accelerometer output is given to the ADC and the output of ADC is read by micro-controller. The software developed in such ways that lower and upper limit of axis of movement is recoded. Every time movement of leg takes place it is compared with previous value of record. If there is difference between two values, it is counted as step one. When the number of steps taken is more it means that physical activity of animal is increased which is clear indication of estrus period.

The vaginal temperature read every after two milliseconds by micro-controller. Then micro-controller reads the data, display it on LCD and send the data to the PC.

V. Results

The Mount count value, the steps taken by the animal and the vaginal temperature shows the estrus stage of that animal. If mount count number on VB window display is more, the change in vaginal temperature as well as steps taken are also increased, this is clear indication of animal in estrus condition.

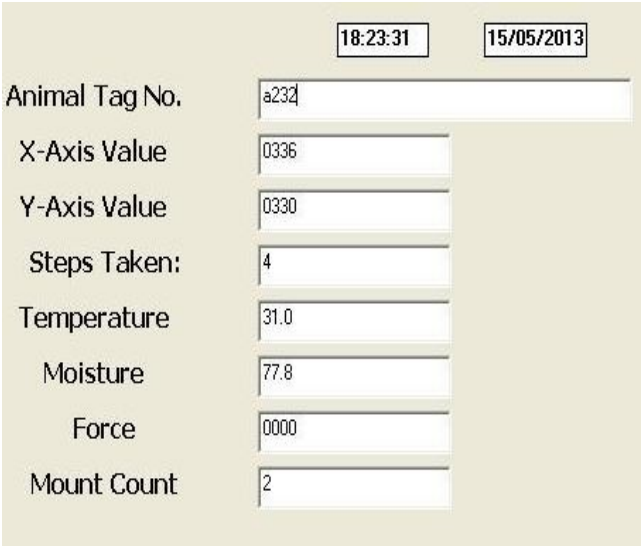

Fig.14. Screen shot of PC screen

Conclusion

The proposed system for the estrus detection is new

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technology where three separate symptoms of estrus period are detected, recorded and displayed at the same time. As there is detection of three parameters the chances of false estrus detection is very low and by just observing the LCD display and the VB screen anyone can realize the status of that animal. This technology not only reduces human efforts but also cost effective one. Initial investment is also less as compared to other estrus detection aids. Device is easy to use, maintenance free, waterproof, robust and Battery can be replaceable. Device can be easily detached from the animal after estrus period detected and can be attached to the other animal on the herd. As mounting, vaginal temperature and physical activity are three important parameters for estrus detection so combining them makes a powerful technology for estrus detection. This device helps to improve the rate of Artificial insemination which eventually increases the milk production.

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